Accuracy and Precision of Biplanar Videoradiography to Quantify Tibial Fracture Motion After Fixation

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Purpose: Understanding the biomechanical factors contributing to fracture healing necessitates a precise and minimally invasive quantitative system. Dynamic Biplanar Videoradiography (DBVR) represents an advanced imaging technique that can observe and quantify 3D bone movements in real time during muscle-driven activities. The purpose of this study was to demonstrate the feasibility of using DBVR paired with radio-opaque markers to quantify interfragmentary fracture motion in humans.

Methods: In total, three patients with tibial diaphyseal fractures treated with an intramedullary nail were included. Three to five radio-opaque Tantalum beads were implanted non-collinearly into the tibia immediately above and below the fracture site. DBVR imaging was conducted at 6, 12, 24, and 36 weeks postoperatively during weight transition and walking gait activities. The CT scans for each subject were segmented to acquire bone models of the proximal and distal tibia segments to acquire locations of the radiostereometric analysis (RSA) bead centroids and to determine anatomic coordinate systems. Afterward, the 3D to 2D registration of movement trials was performed using the following two methods: (1) RSA method to locate the centroids of the beads in each frame, and (2) model-based method to register the contours of the bone models to the DBVR images frame-by-frame semi-automatically.

Results: On average, the RSA method demonstrated submillimeter precision, ranging from 0.12 mm to 0.29 mm (0.19 ± 0.09 mm). Similarly, the accuracy ranged from 0.36 mm to 0.40 mm (0.38 ± 0.02 mm). The model-based method also showed submillimeter precision and accuracy but higher magnitudes. The precision of the model- based method ranged from 0.50 mm to 0.58 mm (0.54 ± 0.04 mm), and the accuracy ranged from 0.68 mm to 1.41 mm (1.04 ± 0.37 mm).

Conclusion: This study successfully validated the use of DBVR for measuring interfragmentary motion at tibial diaphyseal fracture sites. The RSA method demonstrated high precision (0.19 mm) and accuracy (0.38 mm), confirming that DBVR can reliably assess interfragmentary kinematics. Future clinical studies using this technology are needed to determine clinically significant changes and assess whether model-based tracking alone is sufficient or if RSA beads are necessary for accurately monitoring fracture motion and union over time.